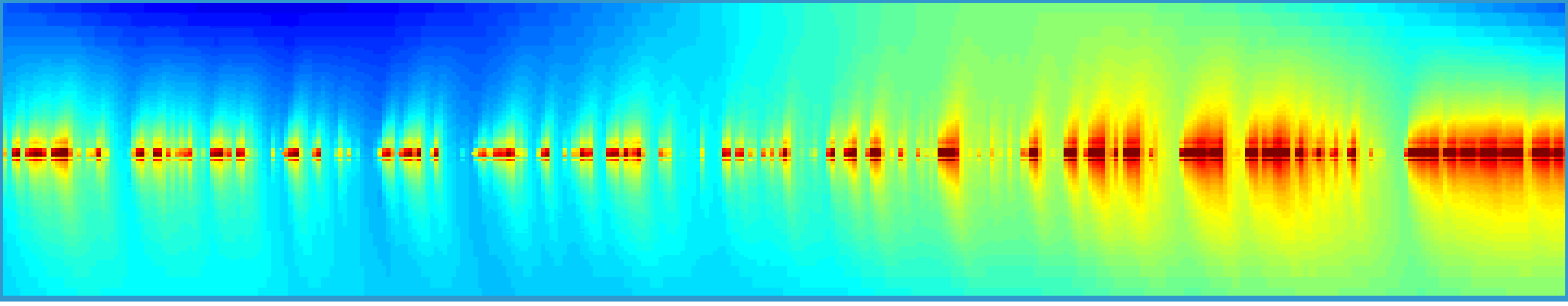
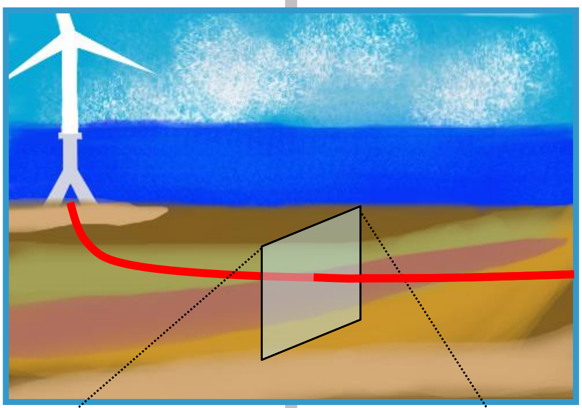


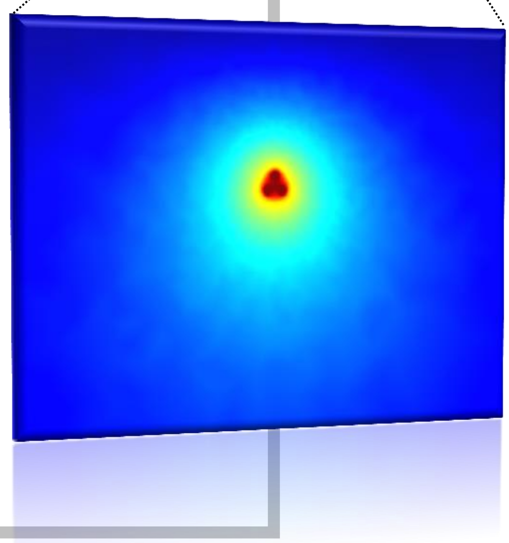
FIELAX CableRouteModel

The FIELAX CableRouteModel is a Finite-Element-Method (FEM) based model of temperature evolution in marine sediments. The model considers both, the seasonal forcing from varying bottom water temperatures (bwt) and also the heat loss of buried energy cables. For realistic outputs the FIELAX CableRouteModel uses measured thermal diffusivities (e.g. from a FIELAX HeatFlowProbe measurement) combined with approximated bwt-data. Result of the model is the temperature field around the cable, allowing assessment of the minimum burial depth and/or the maximum heating of the cable constrained by the 2K-criterion.

What are the benefits of the CableRouteModel?

- Seasonal forcing, geothermal heat flow and internal sources (such as energy cables) have to be considered to assure realistic modeled temperature evolutions
- The burial depth of energy cables is an enormous cost-factor, thus a realistic minimum burial depth can save time and money
- Minimum cable diameter (i.e. material costs) can be determined for any environment and forcing





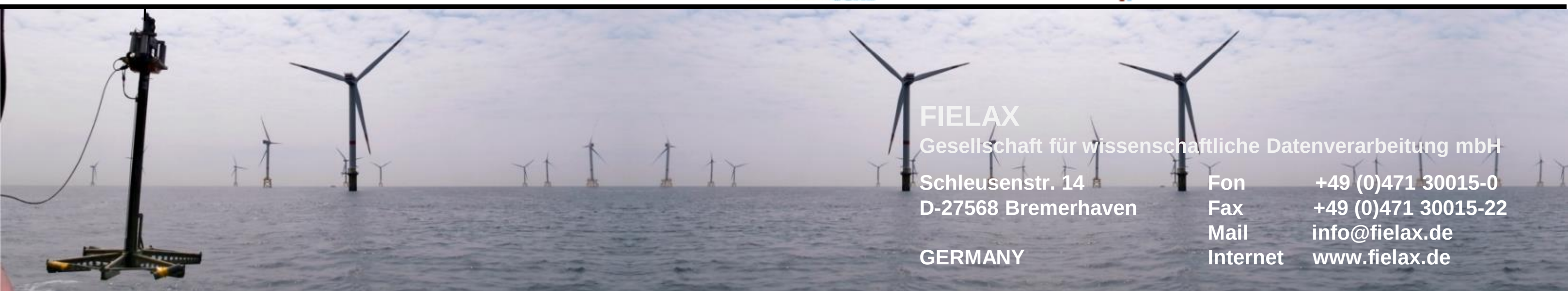
Model INPUT

- Customers power cable properties
- Customers power load functions
- Measured thermal diffusivity (HeatFlowProbe and/or VibroHeat)
- Seasonal forcing approximated over the whole route or changed for individual sections

Model OUTPUT

- Temperature field around the cable
- Minimum cable burial depths in accordance with the 2K-criterion
- Temperature data in the cable itself for better dimensioning
- Sections of the cable route can be treated separately and minimum burial depths can be fitted to the varying thermal properties

Selected references:



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Modeling sediment's temperature

On the right modeled sediment temperatures for a power cable buried in 1,5 m depth are shown for three different power loss scenarios:

- Constant power loss of an average of 50 W/m (**Figure 1**),
- Peak power loss of 100 W/m at day 30 (**Figure 2**) and
- Realistic power loss time series adopted from wind data **(Figure 3**).

All examples show the modeled sediment temperatures at the top, the power loss scenario in the middle and at the bottom the temperature deviation in 20 cm depth between a point vertically above the cable and a reference point in 12 m horizontal distance (2K-criterion).

Note the retardation of the sediment temperature in 20 cm depth after peak event (Figure 2, bottom). **Note** that a peak loss will cause higher temperatures in the sediments, when it has not had the time to cool down completely (Figure 3).

Also shown in **Figure 4** is the determination of minimal burial depths along a cable route with seven sections of varying thermal diffusivities.

Facts of the FIELAX CableRouteModel

- Finite Elements Modeling with approved MATLAB routines
- Modeling along 30 m in horizontal and 15 m vertical extensions
- Mesh-size adjustable to meet desired accuracy
- Thermal diffusivities from file (e.g. from the FIELAX HeatFlowProbe data analysis) or entered manually
- Implementation of every kind of time-variable seasonal forcing
- Planning of optimized cable route burial with respect to measured thermal diffusivity structures
- Optimization of cable design regarding the marine sediments thermal structure

Reference

- Müller, C., Miesner, F., Usbeck, R. & Schmitz, T. (2013), 2K-criterion: measuring and modelling temperatures and thermal conductivities/ diffusivities in shallow marine sediments, Proc. Conference on Maritime Energy 2013, TUHH, Hamburg, pp. 475 - 490

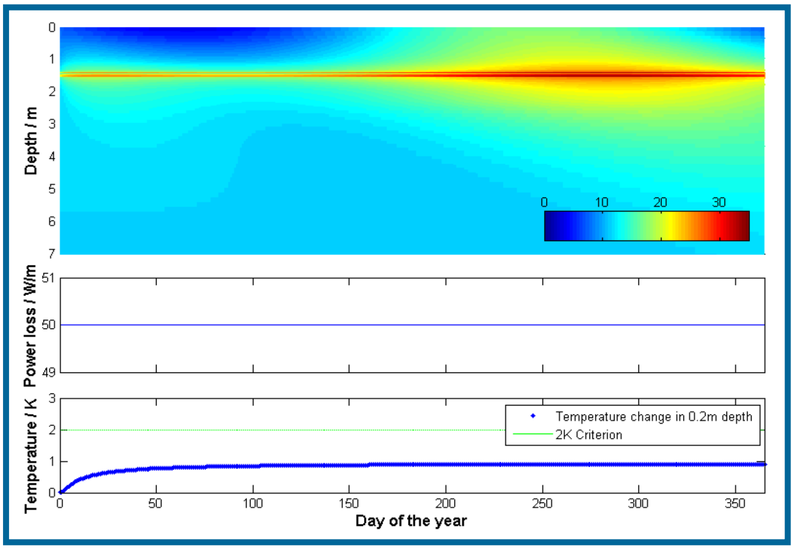

Figure 1: Model temperature for cable with 50 W/m power loss

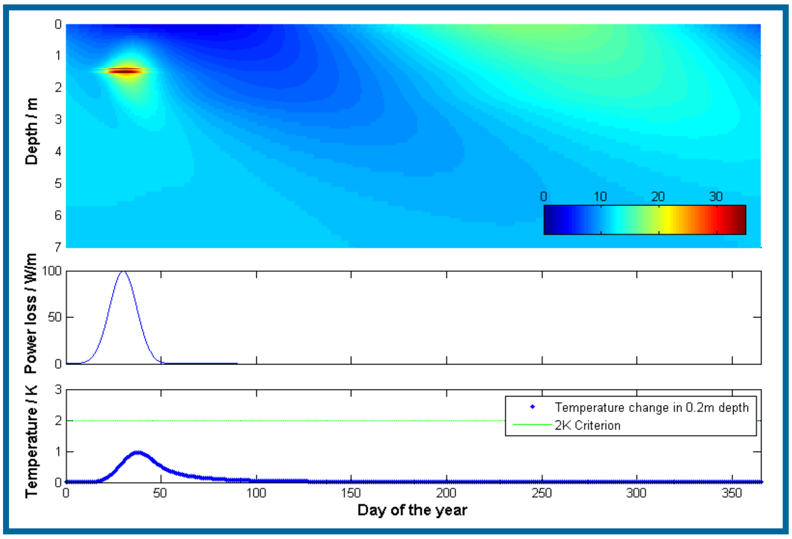

Figure 2: Model temperature for 100 W/m peak power loss

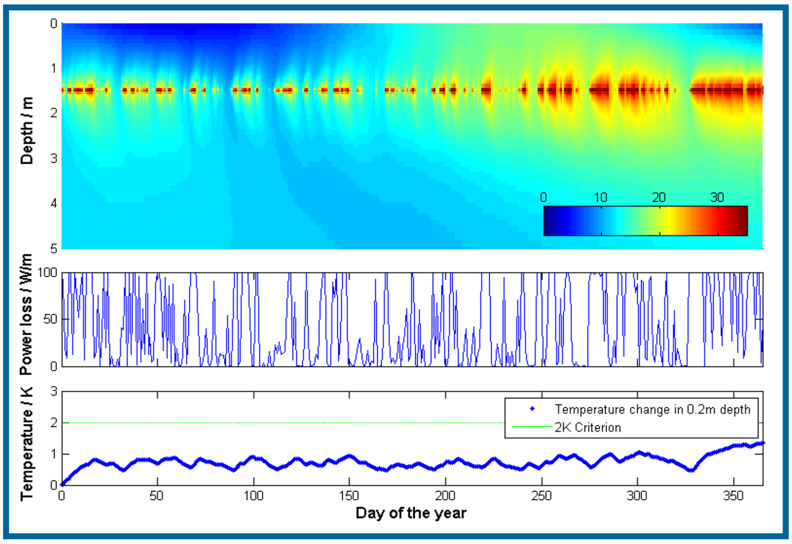

Figure 3: Model temperature with realistically varying power loss

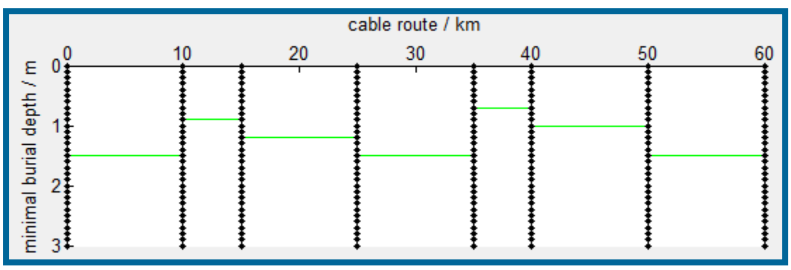

Figure 4: CableRouteModel output image with minimum burial depth for different sections of the route